

An Open-Source Framework for Surgical Subtask Automation

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Abstract— Robot-Assisted Surgery (RAS) is becoming a standard in Minimally Invasive Surgery (MIS). Despite RAS’ benefits and potential, surgeons still have to perform themselves a number of monotonous and time-consuming subtasks like knot-tying or blunt dissection. Many believe that the next big step in development is the automation of such subtasks. Partial automation can reduce the cognitive load on surgeons, supporting them to pay more attention to the most critical elements of the surgical workflow. Our aim was to develop a framework to ease and fasten the automation of surgical subtasks. This framework was built alongside the da Vinci Research Kit (dVRK), while it can be ported easily onto further robotic platforms, since it is based on the Robot Operating System (ROS). The software includes both stereo vision-based and hierarchical motion planning, with a wide palette of often used surgical gestures—such as grasping, cutting or soft tissue manipulation—as building blocks to support the high-level implementation of autonomous surgical subtasks. This open-source surgical automation framework—*iRob-Saf*—is available at <https://github.com/ABC-iRobotics/iRob-Saf>.

I. INTRODUCTION

The headway of MIS revolutionized surgery with smaller incisions, leading to lower risk of complications and faster recovery. Teleoperated surgical systems are able to reduce the fatigue of the surgeon originating from cumbersome postures and the limited range of motion. Nevertheless, the technique presents serious challenges to the surgeons, like the limited range of motion, or weary positions. To reduce these, the teleoperated Robot-Assisted-MIS (RAMIS) approach was introduced, such as the da Vinci Surgical System (Intuitive Surgical Inc., Sunnyvale, CA) [1].

The next step in the advancement of MIS appears to be partial automation. The surgical workflow of the RAMIS procedures often contains time-consuming and monotonous elements, like suturing or knot-tying, the automation of these—so-called subtasks—can reduce the fatigue and the cognitive load on the surgeon, who can hence pay more attention on the critical parts of the intervention.

During the last few years, the automation of surgical subtasks became a prevailing topic in the research of surgical robotics. A number of autonomous surgical subtasks, like dedebriment, suturing, palpation, blunt dissection or shape cutting are already implemented, or being currently developed by various research groups [2][3][4][5][6][7]. Our aim was to develop an open-source framework to support such

projects; provide software packages that already implement basic functionalities, becoming universal building blocks in surgical subtask automation. The basic architecture of this software package—the *iRob Surgical Automation Framework*, or *iRob-Saf*—is presented herein.

II. MATERIALS AND METHODS

Most of the research centers working on partial automation in surgery are utilizing the 1st generation da Vinci alongside the dVRK), or the Raven platform [8], both employing the the ROS for programming. Since our lab employs the dVRK, the *iRob-Saf* is built on this, with a ROS interface for future portability.

III. THE ARCHITECTURE OF THE FRAMEWORK

A system, performing a surgical subtask autonomously, can be assembled from the nodes of *iRob-Saf* based on the principle shown in Fig. 1.

A. Sensory inputs

The endoscopic camera image is undoubtedly the most important information source in RAMIS. It does not require the placement of any additional instrument into the already crowded operating room. In *iRob-Saf*, the video stream—preferably stereo—can be provided by any kind of camera, e.g., USB webcams, or the stereo endoscope of the da Vinci, as long as it is interfaced into a ROS topic.

The algorithms usable for perception are out of scope of the current work, however, the framework offers a pre-built infrastructure to run those, with the required input and output channels. It is important to note that further sensor modalities, like force sensors, can also be easily added to the existing infrastructure.

B. High-level robot control

The arms of the da Vinci surgical robot are interfaced by high-level robot control nodes, one node per arm. These are responsible for executing the trajectories generated by higher level nodes, while checking for errors from the robot. The trajectories are sent through ROS actions instead of topics, which are more favorable in environmental interaction scenarios. ROS actions makes it possible for the higher-level node to work on something else during action execution, e.g., monitoring the environment, or send actions to another node. Moreover, actions provide the ability to send feedback and the result of the action, or preempt the action with another, e.g., if any environmental change makes it necessary.

These high-level robot control nodes are robot-specific, but their interface to the other nodes of the framework is

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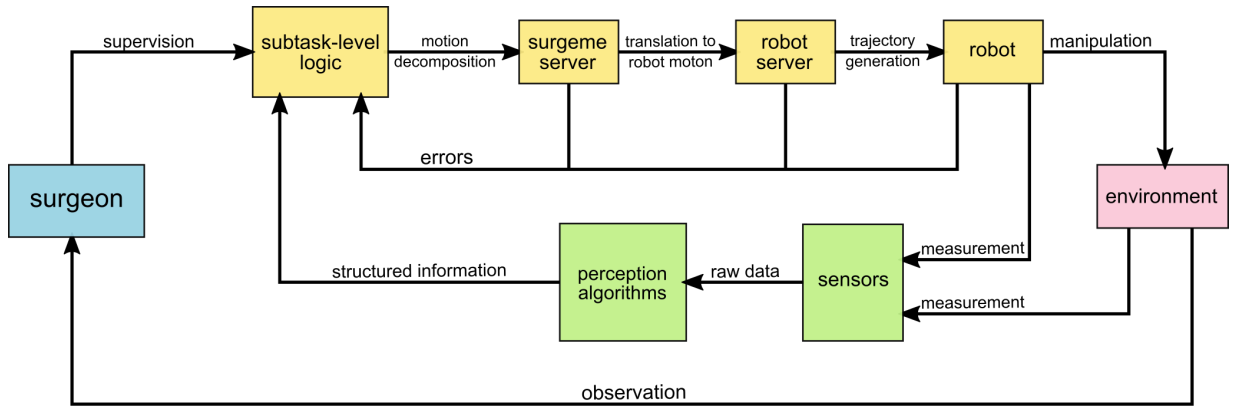


Fig. 1. Flow diagram about the principle of partial automation. The required action is chosen by the subtask-level logic, based on perception of the environment and the commands received from the surgeon; the robot motion is generated by a hierarchical network of nodes, and executed by the robot under permanent monitoring of the surgeon.

universal. This means that the usage of another type of robot arm requires only the implementation of the high-level robot control node itself.

C. Motion decomposition

Laparoscopic surgical motion can be decomposed to components hierarchically [9][10]. The granularity level that can be used most easily to build a motion library is probably the level of gestures—so called surgemes. A library was implemented, offering a number of surgemes, such as *grasp*, *cut* or *place object*. These surgeme actions are parameterizable, and also connected through a ROS action interface. The implemented surgemes are able to do the necessary safety checks, e.g., the proper instrument is used for the current surgeme. Further surgemes can be implemented based on the existing ones, and to be added to the library.

D. Subtask-level logic

The whole system is controlled by a subtask-level logic node. This receives the information from the perception nodes, handles errors, user (surgeon) interactions, and contains and performs the specific workflow of the current subtask.

IV. DISCUSSION

An open-source, ROS based software package to ease surgical subtask automation is presented. This framework interfaces sensory inputs, perception algorithms and robots, and contains a surgeme-level motion library. The whole system can be controlled by a subtask-level logic ROS node, tailored to the needs of the current subtask to be automated. The iRob Surgical Automation Framework—iRob-saf—is available at <https://github.com/ABC-iRobotics/iRob-saf>, and is being continuously developed and updated.

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